ESD-TDR-64-609

DECISION SCIENCES LABORATORY
BIENNIAL PROGRESS REPORT
JULY 1962 THROUGH JUNE 1964

TECHNICAL DOCUMENTARY REPORT ESD-TDR-64-609

OCTOBER 1964

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
L. G. HANSCOM FIELD, BEDFORD, MASS.

ESD-TDR-64-609

DECISION SCIENCES LABORATORY
BIENNIAL PROGRESS REPORT
JULY 1962 THROUGH JUNE 1964

TECHNICAL DOCUMENTARY REPORT ESD-TDR-64-609

OCTOBER 1964

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
L. G. HANSCOM FIELD, BEDFORD, MASS.

ESD-TDR-64-609

DECISION SCIENCES LABORATORY
BIENNIAL PROGRESS REPORT
JULY 1962 THROUGH JUNE 1964

TECHNICAL DOCUMENTARY REPORT ESD-TDR-64-609

OCTOBER 1964

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
L. G. HANSCOM FIELD, BEDFORD, MASS.

ACKNOWLEDGMENT

The Decision Sciences Laboratory gratefully acknowledges the effort of Walton F. Dater, Jr., Capt., USAF, who assembled the material and developed the organization and format for this progress report while participating in the USAF Academy Summer Field Program, June through August 1964.

FOREWORD

This report summarizes the activites of the Decision Sciences Laboratory and describes achievements, progress, results obtained by the Laboratory scientists in the past two years.

FOR THE COMMANDER

Roy Morgan

ROY MORGAN, Colonel USAF
Director, Decision Sciences Laboratory

TABLE OF CONTENTS

ABOUT THE DECISION SCIENCES LABORATORY

General Definition

The Decision Sciences Laboratory (DSL) is a laboratory concerned primarily with the behavior of man in complex military environments involving the presentation and processing of information. It is a laboratory especially interested in exploring, defining, and effecting the most efficient interaction between man and machines in Military Information Systems currently in use or anticipated by the United States Air Force and related Department of Defense agencies.

DSL is an Air Force organization, directed by an Air Force officer, and its mission is totally military. As a military organization, however, it is unique in that the professional staff is approximately 68 percent civilian. The predominant scientific dicipline of the staff is psychology, but is augmented by electronic engineering, mechanical engineering, mathematics, psycholinguistics, and operations analysis. The academic achievement level of the professionsals is, in almost every case, well beyond the Master's Degree.

In the organizational structure, the laboratory is a component of the Electronic Systems Division (ESD), and is directly under the Deputy for Engineering and Technology. ESD, along with several related facilities, form the complex of technological activities on and in the environs of L. G. Hanscom Field, Bedford, Massachusetts. Approximately eight thousand people are employed by ESD, which is a major branch of the Air Force Systems Command (AFSC), one of the major Air Force Commands.

Mission

The Decision Sciences Laboratory initiates exploratory development programs; that is, it estimates and examines future operational requirements of the Air Force, primarily in the area of information processing systems, and determines from such investigation and consideration the

implications for man-machine interaction. Attempts to fill critical gaps in knowledge about human performance which become evident by this process are made through exploratory development projects under each program. Most of the experimental work on these projects is conducted at the laboratory, although it is sometimes expedient to carry on certain portions through contracts negotiated with particular industries or academic institutions where critical or otherwise unavailable facilities can be utilized. DSL is also responsible for designing, developing, procuring, evaluating, managing, and updating certain display components of Air Force electronic systems. Further, it provides engineering services to all elements of the Electronic Systems Division within the area on display characteristics, human performance, and man-machine relationship problems for both present and future Air Force Military Information Systems, needs.

Philosophy

In general. The paraphrase of the formal mission statement in the preceding paragraph only barely suggests the import of the Decision Sciences Laboratory's function for electronic system design technology. In its present state of development, the technology is very advanced in the production of sophisticated hardware - computers, sensors, and so on. The state-of-the-art is advancing rapidly in developing means by which to use this equipment more effectively - in programming computers, for instance. But it is embryonic in its comprehension of how man might be used most efficiently in electronic systems - in knowing how man uses the information supplied by the system to make decisions, in recognizing the implications of decision making behavior on displayed information from computers, and in understanding how men and computers interact.

In particular. In the Decision Sciences Laboratory, ESD possesses a unique professional and technical potential in a most critical part of total system design, namely in defining man's part in a system. Electronic systems are merely hardware - impressive, maybe, but little more without their users. Total electronic systems include people. And man,

in the chain of related events from observing physical phenomena through collecting and analyzing data about them, to choosing one from many possible courses of action, is probably the most important link. He is most important in two ways. (1) Man has the "last word". He is the agent which must effect the appropriate decision after sensors and computers have collected, processed, and presented the data about an attacking enemy force. And that decision may have consequences affecting the future of civilizations. (2) Very little is known about man, or about the human element in the pressures of a multi-machine information system environment, about man's behavior as he operates such complex equipment, evaluates a complex military situation, acts as commander and controller, and ultimately makes an involved decision. These functions, along with the most "human" of all man's capabilities - improvisation, inventiveness, imagination, can doubtless never be duplicated electronically.

So we must make most efficient usage of this most important part of an information system and augment his unique capabilities. To do this, we must learn a great deal more about him than is now known. What processes underlie his very long-term memory for material which would take literally millions of binary decisions to describe? Is man a single-channel information processor? What data does he use in selecting alternative actions? How does he weigh and manipulate these data? How much data can he be expected to evaluate? How fast? What form should the data take to be most useful to him, and thus the system mission? The answers to these and many similar questions are vital, both in specific, concrete situations in the "real world" and in more general theoretical settings, not only so we can better use man in military systems, but so we can better understand man himself. The technical program at the Decision Sciences Laboratory is directed at answering these types of questions about man as the modern military commander, controller, and information processor, and man in his own right, so that it can design and develop machines to serve him better.

<u>Mode of operation.</u> Finally a word should be said about how the laboratory must proceed in order to accomplish the goals embodied in its philosophy.

The ability of DSL to make significant contributions to systems, either in the design or in the operational stage, is entirely dependent on its being involved in research which is in the context of total system design. That is, in order that the findings of research might have direct application, be useful here and now in information systems, the laboratory must be aware of the direction and extent of progress in all the other technological areas. Only by so doing can it direct and advance its own research so as to advance the whole state-of-the-art purposefully.

Background and History

The history of solving problems arising from man's interacting with machines has, of course, been long. We need not trace it here. Suffice it to say that laboratories, functioning much as DSL does, have an established place throughout the whole range of modern industry. They are usually called human factors departments, experimental psychology laboratories, or human engineering groups, and they all seek more knowledge about man's capabilities and limitations when he operates, maintains, and derives benefits from machines.

The Decision Sciences Laboratory has been in existence for nearly twenty years under many and various organizations and aliases. It grew out of the Aviation Psychology Program of World War II. Shortly after the war it became a part of the Medical Section of the Strategic Air Command at Andrews Air Force Base, Washington, D. C. In 1948, it was housed at the Naval Research Laboratory, also in Washington, and, as the Human Resources Research Laboratory, was responsible directly to Air Force Headquarters. In 1952, it became part of the newly formed Air Research and Development Command (now AFSC), and was renamed the Human Factors Operational Research Laboratory. The Research and Development Command organized a group of "research centers" located throughout the country, and in 1954, it was renamed the Operational Applications Laboratory and attached to the Cambridge Research Center at Hanscom. Finally, in 1961, when the Research and Development Command was renamed the Systems Command and reorganized into Systems Divisions, the laboratory

became part of the Electronic Systems Division, and shortly thereafter it assumed its present name, the Decision Sciences Laboratory.

All this time, DSL's primary mission has been to conduct research in human information processing to provide technical support for the development and testing of Air Force systems. Despite name changes, the effort has all been in one direction and in line with Air Force mission requirements.

Character of Manpower

As mentioned earlier, one of the singular features of DSL is the stature of the professional capability which is unique in the federal service.

Degree	Number	Percent
Bachelor's only	4	10%
Bachelor's "plus"	6	15%
Master's only	1	2%
Master's "plus"	16	40%
Ph. D.	13	33%
	40	100%

At this writing, five of the people working on Ph. D. programs will complete them within the year, raising the number with doctorates to 18 or nearly 50%.

The number of years of professional experience ranges from two to twenty-three, and the average per man is eleven and a half. The backgrounds and interests of the staff members cover almost the whole gamut of psychology, except the primarily clinical. It is worth noting, however, that the great weight of experience has been in working with human factors problems of primarily military significance.

The "Automated Laboratory Facility"

Since the fall of 1961, DSL has been developing and using what has come to be called its "Automated Laboratory Facility". The nerve center is a small, rapidly operating and expandable digital computer which is

designated the PDP-1 by its manufacturer, the Digital Equipment Corporation of Maynard, Massachusetts. This computer is not used merely as a data collector, processor and evaluator. It really has two major purposes: (1) to increase greatly the efficiency of experimentation in terms of time and experimental control and (2) to permit kinds of experimentation not possible with conventional techniques. In addition, and probably of most immediate importance to the Air Force mission, some programming techniques developed specifically as experimentation devices evolve as products which are directly applicable to information systems.

Increased efficiency. The computer increases the efficiency of experiments in three ways. (1) It saves time. Computer programs, which will generate enormous quantities of precisely defined stimulus materials in minutes instead of weeks or months, can now be written almost as easily as a description of the experimental design. Programming is constantly being functionally modified so that the experimenter needs very little specialized knowledge of computers, per se. (2) It guarantees that specialized equipment, made compatible with the computer, will be more reliable and effective apparatus. Steps are being taken which will permit the computer to be used in conjunction with many specialized stimulus generation and presentation devices. It will soon be possible for the computer to select, connect, continuously calibrate, maintain,. and operate such devices as audio-signal generators, monochromators, and other equipment needed to provide stimuli for particular experiments. All this can be accomplished in a matter of seconds by the program written for the experiment. This type of control will permit, in time, several experimenters to use the same specialized reliable devices concurrently instead of reserving them for a single job at a time for the sometimes long duration of the experiment. (3) It conserves manpower. The computer can effect great economy, and also a much higher level of standardization, by actually monitoring experiments. It can instruct subjects, test their understanding of instructions, present stimuli, record

responses, and process data. It thus frees experimenters and assistants from the drudgery of collecting data, and allows more time for intellectual evaluation and study of the relevance of the results. It assures perfect standardization of conditions, and it does, at least, preliminary data processing before the subjects leave the experimental room. Such immediate processing could take the experimenter days or weeks to accomplish.

Increased experiment potential. Few of the features of the "Automated Psychological Laboratory" described above permit very much really new at the present time. Taken together, however, they now greatly speed the research process, making results available in a fraction of the time taken up by conventional methods, allowing the design and completion of experiments, heretofore prohibited by complexity, and signalling the entrance of "blind alleys" before really significant effort has been expended in their direction. The real "breakthrough" realized by using these new techniques is not nearly so obvious, or so simple to illustrate, but its nature can be indicated. An experimental design need not be nearly so detailed as it formerly had to be. Stimulus values need not be exactly specified before the data are collected, and the exact amount of data to be collected can be "played by ear" because statistical evaluation of the adequacy of the data can be carried on almost simultaneous with the evaluation of data. Experiments themselves can be dynamic: the character of the next stimulus presentation can be made to be a function of the sequence of responses preceding it. In a decision making study, for example, it might well be desirable to play a two-sided "game" in which the subject's decision determines what sort of information about an attacking enemy force must be displayed to him next. Flexibility in experimental design and a dynamic experimental procedure then, are the two features afforded by the computer which greatly increase DSL's potential at the present time.

PROJECTS

DSL's professional staff identify and define the problems to be solved, by examining both current and future operational needs of the Air Force. These are embodied in Technical Development Objectives (TDO's) which specify the entire range of operational requirements. The laboratory searches those areas likely to be significant for reliable information systems development - areas such as Human Performance, Computer and Information Processing Techniques, Intelligence Techniques, and Communications. As the outline of mission requirements states, the procedure is to analyze from the TDO's implications for man-machine integration, and to identify critical gaps in the knowledge about human performance which are brought to light. Once a gap is identified, the problem of filling it is attacked through an exploratory development project which is directed by one of the division chiefs. This scientist is responsible for initiating the project - for justifying it in terms of Air Force needs, for specifying the objectives and the approach, for subdividing it into a number of workable tasks, for estimating cost and manpower requirements, and for obtaining ESD approval for its exploitation. Then the scientist is responsible for its general administration, and for documenting its progress in terms of solution of the overall problem.

Project Titles

DSL has for some time been pursuing three projects and one task which is part of a project managed by another activity. These are (1) Project 7682: "Man-Computer Information Processing", (2) Project 2806: "Dynamic Man-Computer Interaction", (3) Project 2808: "Psychoacoustic Standards in Voice Communication System Evaluation", and (4) Task 469003: "Human Information Processing" (under Project 4690: "Information Processing in Command and Control").

Nature of the Projects

Each project embraces an area approaching a main branch of the science; even the tasks into which each is divided are major efforts, and are further

broken down into a number of related studies and experiments. One experiment leads logically to another. The projects, therefore, have no completion dates; they are continuing in nature. Occasionally, as new fields of inquiry are opened, a new project will be split off from an old one, or as tasks progress toward completion, several projects will be incorporated into one, as when "Man-Computer Information Processing" was recently realigned to incorporate four other projects.

The projects themselves do not mutually exclude one another, and much of the experimental work is directly relevant to more than one project, all of which are directed toward the specification of human behavior. Studies of human information processing, for instance, are of great importance to all the projects. The projects do not represent the whole continuum of psychological inquiry. As mentioned above, they are designed to fill system needs which are evaluated as being pressing. So by its nature the total research effort cannot possibly be exhaustive.

Each project has had a rather long history during which it has incorporated some tasks and concluded others. As implied, there are tasks under particular projects which quite logically could be justified as being part of another. For this reason, the following section on progress is organized into research areas which will be more meaningful and cohesive to readers not completely acquainted with the projects. The purpose of including this section is to indicate more concretely the direction DSL's work is taking, and to list some results realized under the current projects for the record.

The labor represented by DSL's total output over the last two years (July 1962 through June 1964) can be conveniently divided into five areas. Studies have been made of (1) data presentation and display, (2) learning, problem solving and decision making, (3) programmed teaching and automated training, (4) communications and (5) applications, that is, studies and consultations done in direct technical support of a planned or existing system. In this section, a description of each of these areas appears. It is followed by a bibliography of papers and reports, having meaning for the area, completed during the two year period.

Most of the entries in the bibliography have been given ESD Technical Documentary Report (TDR) numbers: a report is assigned a number if it is published either as a TDR, or as an article in a journal or other professional publication. The entries that do not have TDR numbers are unpublished papers which were read at professional meetings. Several entries, which apply to two areas, are included in the two sections of the bibliography to which they apply. The bibliography is designed as a listing of research carried on since the publication of Bibliography of Human Factors Research with Abstracts, 1954 through 1962, (ESD-TDR-63-603).

Data Presentation and Display

Because the reliability of any semi-automated information system depends so heavily on the man involved, it is necessary to describe and measure man's characteristic information processing behavior as precisely and completely as possible. Such behavior is the result of a number of closely related processes which have been intentionally isolated from one another, to as great an extent as possible, so that they can be measured individually. One such process is the manner by which man perceives and stores information.

Objective. The purpose of studies in data presentation and display, then, is to quantify the variables which affect perception and memory so

that it will be possible to specify the particular display features most useful to the human user in a particular information processing task. For example, DSL seeks to be able to specify what sizes, colors, and shapes of symbols, letters, numbers and other coding techniques are best for transmitting data, and what kinds and amounts of data to present so that man can transform them into meaningful information effectively.

Approach. The approach to studies of perception generally involves manipulating quantifiable display characteristics, and measuring the effect of such manipulations on man's ability to detect or identify signals. The display characteristics which have been studied are of many sorts, both auditory and visual. The approach is complicated by the fact that it is extremely difficult to say where man's perception of data stops and his processing of them begins. With the introduction of increasingly complex displays, the approach will be extended in scope to include the increasingly complex effect of "display interpretability", which in this context refers to consolidating, integrating, and evaluating information, and not simply to detection, or the legibility of the display itself.

Progress. Summaries of some of the research efforts will afford some idea of the amount of work accomplished in the area of data presentation and display, and also indicate the diversity of such investigations.

(1) Accuracy and confidence in identifying the unmarked destination of several moving radar blips (targets) decreased as the size of the destination area on the scope was decreased. When targets disappeared for several display sweeps and then reappeared, identification of the correct destination was delayed more than when a target simply did not move for several sweeps or when other targets were present that followed courses in direction other than the destination. Maintaining the positions of targets (trails) on previous moves greatly improved accuracy.

(2) A study has shown that the effect of removing a narrow band of color from white light (daylight) causes the eye to be more sensitive to the removed band. Results indicate that there is more rapid detection of

signals when the target color matches that filtered from the room illumination.

(3) A study was carried on investigating the possibility of utilizing some aspects of shape as a coding dimension. Task difficulty was manipulated by varying the degree of tilt of each form from a standard, and by varying the possible number of tilt positions a form could assume. Results indicate that for most forms, e.g., circles, squares, etc., percent correct identification decreased as difficulty increased, although the absolute number of correct judgments increased.

(4) When accuracy of information processing was compared in situations involving presentation of simple information to a single modality (the ear or the eye) with that involving presentation of similar information to two modalities either successively or simultaneously, the following were indicated: (1) Processing is more accurate when information is presented to two modalities; (2) Processing is more accurate when the information is presented successively to two modalities than when it is presented simultaneously; (3) Accuracy is inversely related to presentation rate and message length, regardless of the manner of presentation.

(5) Evaluation of three reference backgrounds in which three dimensional space is reduced to two dimensional representation revealed that all yield significant increases in viewing time and error rate as either the number of vehicles or the number of orbits per vehicle increases.

(6) It was learned that the binocular field of search in human subjects is ovaloid in shape, with the longer axis horizontal, and with the center lying above the center of the search field. The field expands in area as a function of exposure time. There are frequent irregularities in shape.

BIBLIOGRAPHY

Adams, J. A. (Univ. of Illinois). EXPERIMENTAL STUDIES OF HUMAN VIGILANCE, February 1963. ESD-TDR-63-320, ASTIA No. 408279, Project 9678, Task 967803, Contract No. AF19(604)-5705.

__________. SPATIAL AND TEMPORAL UNCERTAINTY AS DETERMINANTS OF VIGILANCE BEHAVIOR, April 1963. ESD-TDR-63-125, Project 9678, Task 967803, Contract No. AF19(604)-5705.

Adams, J. A. and Boulter, L. R. (Univ. of Illinois). VIGILANCE DECREMENT, THE EXPECTANCY HYPOTHESIS, AND INTERSIGNAL INTERVAL, June 1963. ESD-TDR-63-114, Project 9678, Task 967803, Contract No. AF19(604)-5705.

Adams, J. A. and Humes, J. M. (Univ. of Illinois). MONITORING OF COMPLEX VISUAL DISPLAYS IV: TRAINING FOR VIGILANCE. Human Factors, Vol. 5, 147-153, 1963. ESD-TDR-63-115, Project 9678, Task 967803, Contract No. AF19(604)-5705.

Adams, J. A. and Others (Univ. of Illinois). MONITORING OF COMPLEX VISUAL DISPLAY V: EFFECTS OF REPEATED SESSIONS AND HEAVY VISUAL LOAD ON HUMAN VIGILANCE. Human Factors, 385-389, August 1963. ESD-TDR-63-193, Project 9678, Task 967803, Contract No. AF19(604)-5705.

Baker, J. D. and Organist, W. E. (DSL). SHORT-TERM MEMORY: NON-EQUIVALENCE OF QUERY AND MESSAGE ITEMS, February 1964. ESD-TDR-64-254, Project 4690 Task 469003.

Baker, J. D. and Whitehurst, A. J. (DSL). A COMPARISON OF TWO LOGIC SYMBOL CODING TECHNIQUES IN A SIMULATED DIGITAL DEVICE MAINTENANCE ENVIRONMENT, July 1962. ESD-TDR-62-196, ASTIA No. 283487, Project 9678, Task 967801.

Botha, Beverly and Shurtleff, D. (MITRE Corp.). STUDIES OF DISPLAY SYMBOLOGY LEGIBILITY: THE EFFECTS OF LINE CONSTRUCTION, EXPOSURE TIME, AND STROKE WIDTH. ESD-TDR-63-249, Contract No. AF33(600)-39852.

__________________________. STUDIES OF DISPLAY SYMBOL LEGIBILITY II: THE EFFECTS OF THE RATIO OF WIDTHS OF INACTIVE TO ACTIVE ELEMENTS WITHIN A TV SCAN LINE AND THE SCAN PATTERN USED IN SYMBOL CONSTRUCTION, September 1963. ESD-TDR-63-440, Contract No. AF19(628)-2390.

Chaikin, Joyce D. and Others (Mount Holyoke Col.). MAPPING A FIELD OF SHORT-TIME VISUAL SEARCH. Science, Vol. 138, 1327-1328, 1962. ESD-TDR-62-215, Project 7682, Task 768204, Contract No. AF19(604)-3037.

Clarke, F. R. and Bilger, R. C. (Univ. of Michigan). THE THEORY OF SIGNAL DETECTABILITY AND THE MEASUREMENT OF HEARING, December 1962. ESD-TDR-62-212, Project 7682, Task 768202, Contract No. AF19(628)-257.

Coules, J. and Lekarczyk M. A. (DSL). OBSERVER TOLERANCE OF FORM TRANSFORMATION AS A FUNCTION OF FORM COMPLEXITY, June 1963. ESD-TDR-63-135, ASTIA No. 411240, Project 7682, Task 768201.

Debons, A., Col, USAF (DSL). DISPLAYS IN MANNED SPACE FLIGHT. Paper presented at the American Psychological Association Meeting, 3 September 1963.

_______________. MAN-COMPUTER TRANSFER PROBLEMS: SOME THOUGHTS ON DISPLAY AND SIMULATION RESEARCH. Paper presented at the Human Factors Society Meeting, Palo Alto, Cal., 24 October 1963.

Duva, J. S. and Others (DSL). DISPLAY SHARING THROUGH COLOR FILTERING, II, October 1962. ESD-TDR-62-228, ASTIA No. 288879, Project 9674, Task 967405.

Egan, J. P. (Indiana Univ.) and Clarke, F. R. (Univ. of Michigan). PSYCHOPHYSICS AND SIGNAL DETECTION, November 1962. ESD-TDR-62-305, ASTIA No. 291450, Project 7682, Task 768202, Contract No. AF19(628)-266.

Forsyth, D. M. (DSL). TEMPORAL MECHANISMS ASSOCIATED WITH INFORMATION PROCESSING BY THE VISUAL SYSTEM, August 1962. ESD-TDR-62-207, ASTIA No. 291577, Project 9670, Task 967001, Prepared under Contract No. AF19(604)-8502 with Gaucher Col.

Freeberg, N. E. (Airborne Instruments Laboratory). FORM PERCEPTION IN VIDEO VIEWING: EFFECTS OF RESOLUTION DEGRADATION AND STEREO ON FORM THRESHOLDS, December 1962. ESD-TDR-63-136. ASTIA No. 401654, Project 9674, Task 967403, Contract No. AF19(628)-328.

Gardner, J. R. (SDL) and Hayes, J. R. (DSL). INQUIRY INTO METHODS USED TO OBTAIN MILITARY INFORMATION REQUIREMENTS, May 1962. ESD-TDR-62-302, ASTIA No. 298254.

Goldberg, Susan and Roby, T. B. (Tufts Univ.). INFORMATION ACQUISITION IN A PATTERN IDENTIFICATION PROBLEM, February 1963. ESD-TDR-63-141, ASTIA No. 412275, Project 9678, Task 967802, Contract No. AF19(604)-5727.

Green, D. M. and Sewall, Susan T. (MIT). EFFECTS OF BACKGROUND NOISE ON AUDITORY DETECTION OF NOISE BURSTS. J. Acoust. Soc. Amer., Vol 34, 1207-1216, 1962. ESD-TDR-62-186, Project 7682, Task 768202, Contract No. AF19(604)-7459.

Gruber, A. (Dunlap & Associates, Inc.). SENSORY ALTERNATION AND PERFORMANCE IN A VIGILANCE TASK, September 1963. ESD-TDR-63-605, ASTIA No. 417444, Project 9670, Task 967001, Contract No. AF19(628)-1654.

Hall, R. J. and Others (Hughes Aircraft Co.). A STUDY OF VISUAL DISPLAY ENHANCEMENT AND TECHNIQUES OF COLOR FILTERING, October 1963. ESD-TDR-63-635, ASTIA No. 426265, Project 7684, Task 768402, Contract No. AF19(628)-2906.

Kershner, A. M. (DSL). SPEED OF READING IN AN ADULT POPULATION UNDER DIFFERENTIAL CONDITIONS. J. Applied Psychol., Vol. 48, 25-29, 1964. ESD-TDR-62-192, Project 7682, Task 768201.

Martell, J. (DSL). FOREIGN DISPLAY TECHNOLOGY: STATE OF THE ART. Paper presented at the National Academy of Sciences Meeting, Working Group VI (Visual Displays), L. G. Hanscom Field, Massachusetts, July 1963.

Pollack, I. (DSL). DISCRIMINATION OF SHARP SPECTRAL CHANGES WITHIN BROAD BAND NOISES. J. Auditory Research, Vol. 3, 165-168, 1963. ESD-TDR-63-405, Project 7682.

________. INTERACTION OF FORWARD AND BACKWARD MASKING J. Auditory Research. ESD-TDR-63-636, Project 7682.

________. INTERFERENCE, REHEARSAL AND SHORT-TERM RETENTION OF DIGITS. Canadian J. of Psychol., Vol. 17, No. 4, 1963. ESD-TDR-63-345, Project 7682.

________. VERBAL REACTION TIMES TO BRIEFLY PRESENTED WORDS. Perceptual and Motor Skills, Vol. 17, 137-138, 1963. ESD-TDR-63-341, Project 7682.

Pollack, I. and Boynton, J. (DSL). IDENTIFICATION OF ELEMENTARY AUDITORY DISPLAYS: EFFECT OF UN-BALANCED PROBABILITIES OF OCCURRENCE. J. Acoust. Soc. Amer., Vol. 34, No. 11, 1963. ESD-TDR-63-352, Project 7682, Task 768203.

Pollack, I. and Johnson, L. (DSL). CONTINUING MEMORY SPAN FOR DIGITS. Perceptual and Motor Skills, Vol 17, 731-734, 1963. ESD-TDR-63-430, Project 7682.

________________. MONITORING OF SEQUENTIAL BINARY PATTERNS. Perceptual and Motor Skills, Vol. 16, 911-913, 1963. ESD-TDR-63-342, ASTIA No. 415147, Project 7682.

________________. KEEPING TRACK OF THE IMMEDIATELY PAST STATES OF VARIABLES. Perceptual and Motor Skills, Vol. 18, 55-58, 1964. ESD-TDR-63-429.

Pollack, I. and Rubenstein H. (DSL). RESPONSE TIMES TO KNOWN MESSAGE SETS IN NOISE. Language and Speech, Vol. 6, Part 2, April-June 1963. ESD-TDR-63-337.

Roby, T. B. and Roazen, H. (Tufts Univ.). SIGNAL AND CHANNEL LOAD IN VIGILANCE TASKS. Perceptual and Motor Skills, Vol. 16, 641-647, 1963. ESD-TDR-63-140, Contract No. AF19(604)-5727.

Rubenstein, H. and Pollack, I. (DSL). WORD PREDICTABILITY AND INTELLIGIBILITY. J. Verbal Learning and Verbal Behavior, Vol. 2, 147-158, 1963. ESD-TDR-62-303, ASTIA No. 420088, Project 7682.

Sorkin, R. D. (Univ. of Michigan). AN EXTENSION OF THE THEORY OF SIGNAL DETECTABILITY TO MATCHING PROCEDURES IN PSYCHOACOUSTICS, November 1962. ESD-TDR-62-210, Project 7682, Task 768202, Contract No. AF19(628)-257.

Swets, J. A. (MIT). CENTRAL FACTORS IN AUDITORY FREQUENCY SELECTIVITY. Psychol. Bulletin, Vol. 60, 429-440, 1963. ESD-TDR-62-193, Project 7682, Task 768202, Contract No. AF19(604)-7459.

Swets, J. A. and Green, D. M. (MIT). SIGNAL DETECTION BY HUMAN OBSERVERS, October 1963. ESD-TDR-64-174, ASTIA No. 434825, Project 7682, Task 768202, Contract No. AF19(604)-7459.

Taub, H. A. and Teichner, W. H. (Univ. of Mass.). EFFECTS OF DIFFERENTIAL VALUE AND EXPOSURE TIME UPON THE DETECTION AND MEMORY SYMBOLS IN A VISUAL SEARCH TASK, June 1963. ESD-TDR-63-343, ASTIA No. 408743, Project 9674, Task 967404, Contract No. AF19(628)-290.

Teichner, W. H. (Univ. of Mass.). INFORMATION PROCESSING UNDER SYSTEM STRESS, November 1963. ESD-TDR-63-657, ASTIA No. 430412, Project 9674, Task 967404, Contract No. AF19(628)-290.

Teichner, W. H. and Others (Univ. of Mass.). EXPERIMENTS ON THE EFFECTS OF INPUT VARIABLES ON MULTI-TARGET ALPHABETIC DISPLAYS, July 1963. ESD-TDR-63-546, Project 9674, Task 967404, Contract No. AF19(628)-290.

Vaughan, W. S., Jr. and Virnelson, T. R. (Human Sciences Research, Inc.). INITIAL STEPS IN THE DEVELOPMENT OF AN INFORMATION SYSTEM FOR IDENTIFICATION AND RAID RECOGNITION IN AIR/SPACE DEFENSE VOL. 1, July 1963. ESD-TDR-64-189, ASTIA No. 600538, Project 4690, Task 469003, Contract No. AF19(628)-289.

Watkins, W. H., Maj, USAF (DSL). EFFECT OF CERTAIN NOISES UPON DETECTION OF VISUAL SIGNALS. J. Experimental Psychol., Vol. 67, 72-75, 1963. ESD-TDR-63-202, ASTIA No. 435009.

Watkins, W. H., Maj, USAF, and Others (DSL). AN AUTOMATED FACILITY FOR FORCED CHOICE SIGNAL DETECTION EXPERIMENTATION, April 1964. ESD-TDR-64-383, Project 7682.

Learning, Decision-Making and Problem Solving

Obviously information is displayed for a purpose, and it is man's task to realize the purpose and process such information accordingly. What happens after a man detects the display information with his senses? Initially he must store the information in such a manner that at some point later in time he can retrieve it. Can the behavioral sciences enhance these processes, that is the processes of storage and retrieval, so that such information will be readily available at the time when a problem must be solved or a decision made? Lumped together here are questions the many answers to which are only barely tentative, and in attempting to arrive at valid answers, human factors scientists are investigating extremely complex intellectual processes. The vast amount of scientific research literature focused on such questions does not in all cases apply explicitly to information system problems. Typically, such problems are extremely complex. The research, therefore, must tease out seemingly minor and unimportant bits of knowldge, which eventually can be integrated and allow explicit answers in complex situations. Ultimately we must be able to answer the question, "What is the most effective method by which man can process information, and make decisions in a dynamic, time constrained, multiple-choice situation, in which the task is vital, and the environment stressful?"

Objective. The DSL objective within this general problem area is the investigation of the particular aspects of man's information processing behavior which should be at optimum level in a man-computer, information and communication situation. As in the data presentation studies, the problem is to specify and quantify adequately the myriad of variables which could conceivably affect man as he stores information, solves problems and makes decisions, especially while under pressure or stress. The problem is further complicated by the fact that information and communication functions typically involve a number of people, so the intricacies of group interaction must be brought under study as well.

Approach. Attempts are being made to simulate the complex conditions

described previously so that experimental studies can be made of the relevant variables leading to the most effective dynamic decision-making. The many variables such as the experience and training levels of the operating personnel, levels of complexity of the tactical situation, various levels of work load, amount of pertinent information which must be accessible, and uncertainty of the action outcome, must be manipulated to specify optimum values.

Progress. A number of methods, techniques, and experimental designs have been formulated to provide the best possible interface between men and their computer-centered environments. Further, a number of studies have been completed in an attempt to specify the variables of influence. Summaries of some of the work are presented below.

(1) In a series of studies, the characteristics and limitations of the learning process involved in the immediate retrieval of random information were examined using long series of unrelated words as stimuli. The results indicate the following: (1) As the length of the series is increased, the absolute number of words retrieved increased, on the other hand, the percent retrieved was about the same for all series lengths. (2) Memory for material presented in series can be enhanced by presenting the material in clusters, such as pairs, or quadruples, rather than singly and successively. (3) By manipulation of the number and size of identifiable word classes, e.g., animals, verbal memory is enhanced. (4) Adding novel type material to typical series of material will increase the amount of recall. (5) The Sensory mode or modes of material presentation will affect recall.

(2) Two methods of aiding humans in problem-solving have been developed which have been shown to enhance problem-solving measurably. One method involves the coding of relevant information, the other specific groupings of information. It was also found that under certain circumstances sub-goals may actually impede problem-solving performance.

(3) Since a large class of problems may be represented as verbal mazes, an investigation of verbal maze solution appeared to provide information basic to the general study of problem-solving. In this study, verbal mazes

were designated by lists of paired words, or associates. Each associate defined a connection between two points in the maze. Solution was carried out without the aid of pencil and paper or other visual aid. Both the length of the solution path and the extent of branching in the maze are shown to influence problem-solving behavior. Both results have implications for models of the solution process.

(4) Several experiments have successfully utilized rating scales or measurement techniques by means of which individual decision makers provide additional information beyond their mere choice of alternatives in arriving at a decision. Such information proves to be an important adjunct in evaluating their decision-making performance.

(5) A study concerned with the effect of interoperator interaction patterns upon group performance in problem-solving tasks was carried out. Matrix representations of interaction structures provided indices for ordering tasks along several dimensions. To determine the relevance of the theoretical measures to actual group performance, four-man groups were timed in cooperative problem-solving tasks. Nine groups were given seven trials on each of nine basic types of problems, each requiring a different interaction structure. Significant results from statistical analyses indicate the relevance of the theoretical classification scheme for measurement of actual group problem-solving performance.

(6) A study related to the previous investigation indicated: (1) that problems requiring reaction to environmental changes are more quickly solved under a shared responsibility condition; (2) that problems involving coordination of action among operators are more efficiently solved with a competent centralized authority. Designation of a low aptitude group member as leader produced inferior performance.

(7) Differential effects of speed stress were sought in a complex task including five information processing activities differing in: (1) Spatial and temporal uncertainty of events requiring response. (2) Location in display channels varying in frequency of occurrence of response events. (3) Short-term memory requirements. (4) Perceptual requirements in

event recognition. Highly practiced individuals were found to have evolved a priority strategy based primarily on frequency of response events in different display locations. High frequency tasks, not requiring search, were relatively impervious to stress effects. Lower frequency events, occurring in low priority display locations, gave rise to poorer performance at all levels of stress. Significant performance decrement under stress occurred first in the most complex low probability task which required search and short-term memory.

(8) A computer simulation model has been developed for use in estimating the effectiveness of the human component in man-machine systems with varying task requirements. An operating computer program simulates a hypothetical warehouse inventory problem in which a small team of operators has the task of maintaining certain levels of inventory.

(9) A second computer model has been developed in an effort to simulate certain aspects of group behavior. The elements of the model include a continually fluctuating environment, a set of action agents (sensors and effectors) to operate on it, and a decision agent with the responsibility of maintaining the environment in an optimal steady state by deploying the sensor and effector agents in a way to best counteract the tendency of the environment to deteriorate over time. The focus of interest is the steady state condition of the environment as a function of interaction between such parameters as the following: (1) the change characteristic of the environment; (2) the reliability of the sensing agents; (3) the precision and activity level of the effector agents; (4) information delay within sensor-effector communication link; (5) decision rules with respect to the assignment of sensors and effectors to environmental regions.

BIBLIOGRAPHY

Cameron, D. B. (DSL). POST-DISCRIMINATION GRADIENTS AROUND STIMULI WITH DIFFERENTIAL RATES OF OCCURRENCE IN A DISCRETE RESPONSE TASK, December 1962. ESD-TDR-62-352, ASTIA No. 295583, Project 9674, Task 967406.

______________. ACQUISITION OF A PROBABILISTIC DISCRIMINATION BETWEEN SUBSEQUENT ALTERNATIVE EVENTS, March 1963. ESD-TDR-63-134, ASTIA No. 402493, Project 9674, Task 967406.

Debons, A., Col. USAF (DSL). MAN-COMPUTER TRANSFER PROBLEMS: SOME THOUGHTS ON DISPLAY AND SIMULATION RESEARCH. Paper presented at the Human Factors Society Meeting, Palo Alto, Cal., 24 October 1963.

Edwards, W. (Univ. of Mich.). PROBABILISTIC INFORMATION PROCESSING IN COMMAND AND CONTROL SYSTEMS, March 1963. ESD-TDR-62-345, ASTIA No. 299291, Project 4690, Task 469003 Contract No. AF19(604)-7393.

Farrell, F. and Others (DSL). THE INFLUENCE OF INTERACTION STRUCTURES ON SPEED OF GROUP PROBLEM SOLVING. Paper presented at the American Psychological Association Meeting, Philadelphia, Pa. 3 September 1963.

Goldberg, Susan and Roby, T. B. (Tufts Univ.) INFORMATION ACQUISITION IN A PATTERN IDENTIFICATION PROBLEM, February 1963. ESD-TDR-63-141, ASTIA No. 412275, Project 9678, Task 967802, Contract No. AF19(604)-5727.

Hayes, J. R. (DSL). HUMAN DATA PROCESSING LIMITS IN DECISION MAKING, July 1962. ESD-TDR-62-48, ASTIA No. 283384, Project 2806, Task 280603.

___________. RESEARCH IN PROBLEM SOLVING, PARTS I & II. Paper presented at the Air Force Cambridge Research Laboratory Colloquia, L. G. Hanscom Field, Mass., July and October 1963.

___________. ON THE DESCRIPTION OF SIMPLE LOGICAL PROBLEMS (to be published). ESD-TDR-63-616, Project 7682, Task 768203.

___________. PROBLEM TOPOLOGY AND THE SOLUTION PROCESS (to be published). ESD-TDR-64-441, Project 7682.

___________. ON THE SOLUTION OF VERBAL MAZES. Paper presented at the American Psychological Association Meeting, Philadelphia, Pa., 3 September 1963.

Huggins, W. H. (Johns Hopkins Univ.). INVESTIGATION AND EVALUATION OF NEW APPROACHES TO TEACHING SYSTEM THEORY, September 1963. ESD-TDR-63-602, ASTIA No. 420840, Project 7684, Task 768403, Contract No. AF19(628)-263.

Nakahara, J. and Toda, M. (Tufts Univ.). OPTIMAL STRATEGIES AND HUMAN BEHAVIOR IN FUNGUS-EATER GAME -4, February 1964. ESD-TDR-64-237, ASTIA No. 600823, Project 4690, Task 469003, Contract No. AF19(628)-2450 and -2968.

Nickerson, R. S. (DSL). RESPONSE TIMES FOR "SAME" - "DIFFERENT" JUDGMENTS. Perceptual and Motor Skills (in press). ESD-TDR-64-536, Project 7682, Task 768203.

______________. RECOGNITION MEMORY FOR COMPLEX MEANINGFUL VISUAL CONFIGURATIONS - A DEMONSTRATION OF CAPACITY (to be published). ESD-TDR-64-558, Project 7682, Task 768201.

Nickerson, R. S. and McGoldrick, C. C., Jr., (DSL). CONFIDENCE CORRECTNESS AND DIFFICULTY WITH NON-PSYCHOPHYSICAL COMPARATIVE JUDGMENTS. Perceptual and Motor Skills, Vol. 17, 159-167, 1963. ESD-TDR-63-324, Project 7682.

____. CONFIDENCE RATINGS AND LEVEL OF PERFORMANCE ON A JUDGMENTAL TASK (to be published). ESD-TDR-64-236, Project 7682.

____. EFFECT OF EXPERIMENTER'S VERBAL RESPONSE COMBINATIONS ON CRITERION SHIFTS IN A CARD SORTING TASK: REINFORCEMENT OR INFORMATION? (to be published). ESD-TDR-63-333, Project 7682.

Nicol, Elizabeth H. and Others (DSL). GROUP PROBLEM SOLVING UNDER TWO TYPES OF EXECUTIVE STRUCTURE. J. Abnormal and Social Psychol., Vol. 67, 550-556, 1963. ESD-TDR-63-139, Project 4690, Contract No. AF19(604)-5727.

Roby, T. B. (Tufts Univ.). BEHAVIORAL FREEDOM AND CONSTRAINT (to be published). ESD-TDR-63-547, Project 9678, Task 967802, Contract No. AF19(604)-5727.

__________. BELIEF STATES: A PRELIMINARY EMPIRICAL STUDY, March 1964. ESD-TDR-64-238, Project 4690, Task 469003, Contract No. AF19(628)-2450.

Roby, T. B. (Tufts Univ.) and Nickerson, R. S. (DSL). STEPS TOWARD SIMULATION OF GROUP PERFORMANCE, October 1963. ESD-TDR-63-629, Project 7682, Contract No. AF19(628)-2450.

____. STEPS TOWARD COMPUTER SIMULATION OF SMALL GROUP BEHAVIOR. Paper presented at the Digital Equipment Corporation Computer Users Meeting, Livermore, Cal., 14 - 18 November 1963.

Sheridan, T. B. (M.I.T.) STUDIES OF ADAPTIVE CHARACTERISITCS OF THE HUMAN CONTROLLER, December 1962. ESD-TDR-62-351, Project 4690, Task 469002, Contract No. AF19(628)-242.

Shuford, E. H. (Institute for Research). SOME BAYESIAN LEARNING PROCESSES, October 1963. ESD-TDR-63-623, ASTIA No. 424756, Project 4690, Task 469003, Contract No. AF19(628)-2968.

Sumby, W. H. (DSL). WORD FREQUENCY AND SERIAL POSITION EFFECTS. J. Verbal Learning and Verbal Behavior, Vol. 1, No. 6, 443-450. May 1963 Project 7682, Task 768202.

____________. IMMEDIATE RETRIEVAL OF VERBAL SERIES: I. EFFECT OF LENGTH (to be published). ESD-TDR-64-442, Project 7682, Task 768201.

____________. IMMEDIATE RETRIEVAL OF VERBAL SERIES: II. STIMULUS GROUPING (to be published). ESD-TDR-64-544, Project 7682, Task 768201.

____________. IMMEDIATE RETRIEVAL OF VERBAL SERIES: III. INCREMENTAL OR ONE-TRIAL LEARNING (to be published). ESD-TDR-64-555, Project 7682, Task 768201.

____________. IMMEDIATE RETRIEVAL OF VERBAL SERIES: IV. EFFECT OF CONTEXT (to be published). ESD-TDR-64-556, Project 7682, Task 768201.

Teichner, W. H. (Univ. of Mass.). INFORMATION PROCESSING UNDER SYSTEM STRESS, November 1963. ESD-TDR-63-657, ASTIA No. 430412, Project 9674, Task 967404, Contract No. AF19(628)-290.

Toda, M. (Institute for Research). MEASUREMENT OF SUBJECTIVE PROBABILITY DISTRIBUTIONS, July 1963. ESD-TDR-63-407, ASTIA No. 416405, Project 4690, Task 469003, Contract No. AF19(628)-2968.

_______. OPTIMAL STRATEGIES IN SOME SIMPLE FUNGUS-EATER GAMES, July 1963. ESD-TDR-63-406, ASTIA No. 416153, Project 4690, Task 469003, Contract No. AF19(628)-2968.

_________. MICROSTRUCTURE OF GUESS PROCESSES: PART C, September 1963. ESD-TDR-63-548, Project 4690, Task 469003, Contract No. AF19(628)-2968.

Toda, M. and Shuford, E. H. (Institute for Research). UTILITY, INDUCED UTILITIES, AND SMALL WORLDS, October 1963. ESD-TDR-63-622, ASTIA No. 424752, Project 4690, Task 469003, Contract No. AF19(628)-2968.

_________________________. (DSL). LOGIC OF SYSTEMS - INTRODUCTION TO THE FORMAL THEORY OF STRUCTURE, January 1964. ESD-TDR-64-193, ASTIA No. 469003, Project 4690, Task 469003.

Vaughan, W. S., Jr. and Virnelson, T. R. (Human Sciences Research, Inc.). INITIAL STEPS IN THE DEVELOPMENT OF AN INFORMATION SYSTEM FOR IDENTIFICATION AND RAID RECOGNITION IN AIR/SPACE DEFENSE (VOL I), July 1963. ESD-TDR-64-189, ASTIA No. 600538, Project 4690, Task 469003, Contract No. AF19(628)-289.

Wiesen, R. A. (Univ. of North Carolina). DECISION-THEORETIC AND EMPIRICAL INVESTIGATION OF SOME PROBABILISTIC DISCRIMINATION LEARNING SITUATIONS (to be published). ESD-TDR-64-192, Project 4690, Task 469003, Contract No. AF19(628)-1610.

Weisz, A. Z. and McElroy, Linda S. (Bolt, Beranek & Newman). INFORMATION PROCESSING IN A COMPLEX TASK UNDER SPEED STRESS, May 1964. ESD-TDR-64-391, Project 7682, Task 768201, Contract No. AF19(604)-8449.

Programmed Teaching and Automated Training

The rapid advance of automation in information systems has introduced what might be termed "training dilemma". The problem is that otherwise occupied commanders, controllers, operators, and maintenance personnel must perform quite complex intellectual and perceptual tasks which are both time consuming and difficult to learn.

Objective. By way of working toward a solution, DSL has instituted a vigorous effort in programmed teaching and automated training research. It is attempting to provide the kind of on-site training materials necessary for establishing and maintaining proficiency in the human users of sophisticated electronic equipment. But the need for devices which expedite the learning process does not end with computer operators. People in many jobs requiring the performance of complex tasks or involved decision making can benefit from automated training. Programmed teaching courses, for example, have been developed for teaching managerial techniques such as PERT, described below.

Approach. Because the need is pressing, the research is being carried on throughout the whole continuum of DSL's mission effort, that is, in exploratory and advanced development, in special tests and studies, and in direct support of planned and existing systems of many types. Although the training courses are different, some employ computers and some do not; and although their methods differ widely, they all have much in common. All are tutorial courses which either consist of computer programs allowing the operational computer to be used as a teaching machine, or they consist of textbooks, and all are designed to minimize the need for a human teacher. All teach, test learning, reteach if necessary, and maintain the learning at a level required by the job.

Progress.

(1) One of DSL's contributions which is quite significant,and at the same time illustrative of an automated teaching course, is the course used to teach the PERT management technique. PERT (Program Evaluation Review Technique) is a management tool, now widely in use throughout the

Department of Defense and in industry, which is designed to aid high level managers make decisions about the progress of a program more efficiently. It is a complicated technique, and one requiring considerable time to learn; time, managers can ill afford to spend. DSL developed an automated training course called PERTeach which permits the manager to learn the new technique at his own rate. He can spend as much time in learning at one sitting as his other duties will allow, thus saving him from the necessity of attending a lengthy lecture course. The PERTeach course consists of six volumes, and leads the learner, by very judiciously selected increments, to the learning goal. It constantly requires him to answer questions about what he has learned, and anticipates, analyzes and corrects mistakes. The theory is that such a process will save time in the long run by preventing the learner from forming misconceptions about essential points, misconceptions which would block the ultimate learning goal. PERTeach is the follow-up to an experimental course which was successfully field-tested in 1962-63, and subsequently adopted for use in the Department of Defense PERT Orientation and Training Center. The significance of PERTeach lies in the fact that the theories of learning involved can be generalized to apply to the development of future automated training courses.

(2) Other significant work done in the field by the laboratory includes development of a computer-directed tutorial program for use in "computerized" information systems, a definition of automated training requirements for future information systems, and an automated training technique in man-computer communication which is being tested on the staff of System 473L the Air Force Control System.

BIBLIOGRAPHY

(American Institute for Research). SYSTEM 473L, OTC QUERY LANGUAGE, SELF-INSTRUCTIONAL COURSE, August 1964. ESD-TDR-64-443, Project 7682, Task 768204, Contract No. AF19(628)-2935.

Baker, J. D. (DSL). PROGRAMMED INSTRUCTION AS A METHODOLOGICAL TOOL IN PSYCHOLOGICAL RESEARCH. Paper presented at the First Annual Convention of the National Society for Programmed Instruction, San Antonio, Tex. 28-29 March 1963.

Mayer, Sylvia R. (DSL). RESEARCH ON AUTOMATED TRAINING AT ESD. Paper presented at the First Annual Convention of the National Society for Programmed Instruction, San Antonio, Texas, 28-29 March 1963.

______________. AIR FORCE SYMPOSIUM ON MILITARY MEASUREMENT AND EVALUATION: ON-THE-JOB-CRITERIA. Paper presented at the American Psychological Association Meeting, Philadelphia, Pa., 3 September 1963.

______________. PROGRAMMED INSTRUCTION FOR ELECTRONIC SYSTEMS. Paper presented at the Boston Chapter of the National Society for Programmed Instruction, Wellesley, Mass., 23 October 1963.

______________. PROGRAMMED INSTRUCTION: MILITARY SETTINGS. Paper presented at the Burlington PTA, Mass., February 1964.

Rath, G. J. and Others (Raytheon Co.). THE DEVELOPMENT OF EXPERIMENTAL PROGRAMS FOR AUTOMATED TRAINING IN DECISION MAKING - HANDBOOK FOR PERTEACH COURSE ADMINISTRATORS, July 1963. ESD-TDR-63-606, ASTIA No. 421776, Project 9677, Task 967701, Contract No. AF19(628)-365.

____________________. PERTEACH - THE DEVELOPMENT OF EXPERIMENTAL PROGRAMS FOR AUTOMATED TRAINING IN DECISION MAKING, August 1963. ESD-TDR-63-608, ASTIA No. 421735, Project 9677, Task 967701, Contract No. AF19(628)-365.

Sheridan, T. B. (Bio-Dynamics, Inc.) and Mayer, Sylvia R. (DSL). DESIGN AND USE OF INFORMATION SYSTEMS FOR AUTOMATED ON-THE-JOB TRAINING, I: CONCEPTUAL AND EXPERIMENTAL APPROACHES (VOL. I & II), December 1963. ESD-TDR-64-234, Project 7682, Task 768204, Contract No. AF19(628)-455.

Weiss, E. C. (The Matrix Corp.). A FIELD SURVEY OF A SELF-TUTORING COURSE FOR ON-SITE TRAINING IN SAGE AN/FST-2 TROUBLE-SHOOTING, November 1962. ESD-TDR-62-346, ASTIA No. 296022, Contract No. AF19(628)-242.

Weiss, M. (Raytheon Co.). PERTEACH VOL I THRU VOL VI, March 1963. ESD-TDR-63-198, ASTIA No. 410245, 410273, 411278, 411277, 410244, 409914 , Project 9677, Task 967701, Contract No. AF19(628)-365.

Communications

Communication here refers to the transmission of any information from man-to-man, man-to-machine, or machine-to-man. In other words, the concern here is with at least two different kinds of communication: voice communication, and communication between men and computers. The objective of an information system is to facilitate operational decisions by Air Force personnel. Information transmitted through such systems becomes useful only when it is presented to human beings for interpretation and action. Applied research on human communication aims to determine the limitations and capabilities of sensory-perceptual processes through which information is received by the individual, to identify the significant physical characteristics of information-bearing signals with respect to their psychological consequences and to apply this knowledge to the specific requirements of Air Force information systems. Air Force operations have depended to a critical degree on information transmitted in the form of human speech and presented acoustically to the human receiver. However, information requirements are exceeding the current capabilities of direct talker-listener channels; computerized systems are able to transmit, process, and display far more information than human operators can assimilate through the customary visual and auditory channels. There is an acute need, in the case of voice communication to make most efficient use of human speech and auditory perception. Further, there is an equally acute need to exploit the communicatory potential of computers.

The computer, potentially, can be the mainstay of the commander in military information systems. Yet, the computer will be of little use in the decision making process, if it yields or accepts information slowly or in a form hardly useable by man. It is an obvious necessity for effective advanced information systems that communication between the commander and the computer be made maximally efficient. The communicating language should be one which provides maximum flexibility and speed but does not require the constant mediation of a professional programmer. It is further necessary that the data files of the computer be capable of being updated

rapidly and simply whether information is being fed into storage from one source or a number of sources simultaneously.

Objectives. The objective of the voice communication research is to identify and describe the features of auditory signals which can be most effectively utilized for rapid, efficient and unambiguous communication among operators and decision-makers in information and communication systems. The end-products anticipated are knowledge about the prediction capability for the effects of language and system variables on speech transmission, and the value of extra-intelligibility information contained in the human voice.

The objective of the research in the area of man-computer communication is the development of techniques for permitting real-time interaction between command decision personnel, as an integral part of the information system, and the computer components.

Approaches. The approach in voice communication has involved examinations of the effect of electrical and acoustical system characteristics and of message structure on the human receiver's ability to extract meaningful information from speech signals, and refinement of techniques for measuring intelligibility. Further research is directed at the determination of the communicatory value of non-speech information contained in spoken messages, such as cues by which listeners judge the identity and emotional state of talkers independently of verbal message content.

Two general lines of attack are being pursued to achieve the goal of faster and more flexible communication between command decision personnel and the computer: (1) the development of programming techniques to permit the use of natural English in retrieving information from computer storage; and (2) the development of programming techniques and equipment to permit sharing of computer time among several human communicators.

Progress. Most Air Force communication operations depend on voice communication, e.g., radio or telephone systems. Background noise and noise within the system itself can severely hamper communication and thus curtail vital operations. There have been several efforts made to minimize

the problem, some of which are summarized below.

(1) One has been the investigation of the intelligibility of English language sounds under various conditions of noise competition. A recent series of studies was designed to evaluate a set of words belonging to an identifiable category to serve as aircraft call signs in Air Traffic Control Central (VOLSCAN). The words were tested as a function of certain phonetic and linguistic criteria such as frequency of occurrence in the language, syllabic length, and phonetic structure. From such experimentation, a set of call signs was evolved which minimized ambiguity and confusion.

(2) A simple, valid and reliable talker-listener test (Rhyme Test) has been developed as a means of evaluating communications subsystems. The talker transmits a word through the system, and the listener indicates what word, from a list of rhymed words, he understood as being transmitted. The answer sheets are self-scoring, and provide a diagnosis of system deficiencies as well as an assessment of speech handling capacity. The entire process takes but five minutes to administer -- a considerable reduction from the time taken by earlier tests, and with greater reliability.

(3) A speech communication index meter has also been developed and tested. It is coupled electrically to the system being evaluated. In its present form, it is capable of giving an index of system communication performance in approximately three minutes. Neither this device nor the test described above requires specialized training to use.

(4) One of the most significant undertakings at DSL in the field of man-computer communications is the work being done on adapting the computer to respond to queries in "natural" English as opposed to cryptic computer language. It must be realized here, that such research is at a very early stage of development, but that it is receiving a great deal of attention from many military agencies, private corporations, and universities. The laboratory is concentrating on making it possible to retrieve English sentences from a data file in order of relevance or potential relevance to the question. A recent study has resulted in a procedure for sentence retrieval in response to question

of the form "What do you know about Soviet, Missiles, Mongolian, Border?" The ability of the computer to identify potentially relevant messages depends on a syntax-free associative network rather than on a pre-compiled thesaurus. Thus, a message about "large liquid oxygen shipments to Southern Siberia" would be identified by the computer as potentially relevant to the question above, although there are no synonyms or words in common in both question and message.

We are a very long way from actually being able to give voice messages to a computer and receiving them from it, but exploratory development is proceeding along lines intended to lead to just such an accomplishment. The problem of making the computer "understand", transform sound patterns into electrical signals needed to trigger a response, talkers with radically different speech habits has not yet been quantitatively defined; there is a lack of knowledge about the physical and psychophysical ways in which talker behavior varies. So the present work is aimed at identifying the physical and behavioral parameters differentiating individual talkers, and establishing the range of variation for male talkers.

(5) Some progress has been attained in programming for independent operation of two CRT's connected to the computer. Complete analysis of the requirements for extensive operator time-sharing has been completed, however, programming techniques cannot be developed further until additional computer components are delivered.

BIBLIOGRAPHY

Brown, C. R. and Connolly, D. W. (DSL). TED: A TAPE EDITOR, September 1963. ESD-TDR-62-218, ASTIA No. 285472, Project 2806, Task 280604.

Coules, J. and Others (DSL). ON THE SELECTION OF CODE-NAMES FOR COMMUNICATIONS SYSTEMS, November 1962. ESD-TDR-62-306, ASTIA No. 292264.

Egan, J. P. (Indiana Univ.). and Clarke, F. R. (Univ. of Mich.). PSYCHO-PHYSICS AND SIGNAL DETECTION, November 1962. ESD-TDR-62-305, ASTIA No. 291450, Project 7682, Task 768202, Contract No. AF19(628)-266.

Giuliano, V. E. and Jones, P. E. (Arthur D. Little, Inc.). LINEAR ASSOCIATIVE INFORMATION RETRIEVAL, November 1962. ESD-TDR-62-294, ASTIA No. 296313, Project 5581, Task 558106, Contract No. AF19(628)-256.

Giuliano, V. E. (Arthur D. Little, Inc.). AUTOMATIC MESSAGE RETRIEVAL, November 1963. ESD-TDR-63-673, ASTIA No. 433603, Project 2806, Task 280601, Contract No. AF19(628)-256.

House, A. and Others (Bolt, Beranek & Newman, Inc.). PSYCHOACOUSTIC SPEECH TESTS: A MODIFIED RHYME TEST, June 1963. ESD-TDR-63-403, ASTIA No. 411983, Project 7684, Task 768403, Contract No. AF19 (628)-382.

Pollack, I. (DSL). ARE COMMON WORDS EASIER TO HEAR THAN UNCOMMON WORDS? Paper presented at the Colloquium of the Department of Psychology, Univ. of Mass., April 1963.

________. WORD INTELLIGIBILITY AS A FUNCTION OF WORD PROBABILITY. Paper presented at the Eastern Psychological Association Meeting, New York, 11-13 April 1963.

________. MESSAGE PROBABILITY AND MESSAGE RECEPTION. J. Acous. Soc. Amer., Vol. 36, 937-945, 1964. ESD-TDR-63-434. Paper presented at the Acoustical Society of America Convention, New York, 15-18 May 1963.

________. PROSPECTS IN SPEECH COMMUNICATION. Paper presented at Project Forecast, L. G. Hanscom Field, Mass., June 1963.

________. INFORMATION TRANSMISSION AND INFORMATION REDUCTION. Paper presented at the NATO Symposium on Human Factors, Washington, D. C., August 1963.

__________. VERBAL COMMUNICATION OF EXPRESSIVE MODES. Paper presented at the American Psychological Association Meeting, Philadelphia, Pa., 3 September 1963.

__________. INTERACTION OF TWO SOURCES OF VERBAL CONTEXT IN WORD IDENTIFICATION. Language and Speech, Vol. 7, Part 1, Jan-March 1964. ESD-TDR-63-126, Project 7682.

__________. INTERACTION BETWEEN AUDITORY AND VISUAL INFORMATION SOURCES IN WORD IDENTIFICATION. Language and Speech, Part 2, April-June 1964. ESD-TDR-63-433, Project 7682, Task 768202.

Pollack, I. (DSL) and Pickett, J. M. (AFCRL). THE INTELLIGIBILITY OF EXCERPTS FROM CONVERSATIONAL SPEECH. ESD-TDR-63-360. Paper presented at the 66th Meeting of the Acoustical Society of America, Ann Arbor, Mich., November 1963.

____________________. INTELLIGIBILITY OF EXCERPTS FROM FLUENT SPEECH: AUDITORY VS. STRUCTURAL CONTEXT. J. Verbal Learning and Verbal Behavior, Vol. 3, No. 1, February 1964. ESD-TDR-63-361, Project 7682.

____________________. AUDITORY VS. SYNTACTIC CONTEXT. Paper presented at the Psychonomic Society Meeting, Bryn Mawr Col., Pa., September 1963.

Pollack, I. and Rubenstein, H. (DSL). RESPONSE TIMES TO KNOWN MESSAGE-SETS IN NOISE. Language and Speech, Vol. 6, Part 2, April-June 1963, ESD-TDR-63-337, Project 7684.

Rubenstein, H. (DSL). SYNTAGMATIC ANALYSIS OF ENGLISH. Paper presented at the American College of Neuropsychopharmacology Meeting, Washington, D.C., January 1963.

Rubenstein, H. and Pollack, I. (DSL). WORD PREDICTABILITY AND INTELLIGIBILITY. J. Verbal Learning and Verbal Behavior, Vol. 2, 147-158, 1963. ESD-TDR-62-303, ASTIA No. 420088, Project 7682.

Stuntz, S. E. (DSL). SPEECH-INTELLIGIBILITY AND TALKER-RECOGNITION TESTS FOR AIR FORCE VOICE COMMUNICATIONS SYSTEMS, February 1963. ESD-TDR-63-224, ASTIA No. 402989, Project 7684, Task 768401.

Applications

The work and products listed here are the tangible results of DSL's labor - in the form of knowledge put-to-use. Applications are at the opposite end of the mission effort continuum from exploratory and advanced development projects. They are based on both the results of research and the special competence of the personnel engaged in such research.

Objective. The aim of this effort is applying the principles and techniques developed to systems and situations in the "real world".

Approach. Most of the items included here have been mentioned in other connections earlier, but all of them involve direct system support work. This work includes such things as insuring that operator functions are appropriately allocated, designing equipment for human use, designating personnel and training requirements, programming instruction, and testing and evaluating personnel subsystems. Some of the work is of a consultative nature, in addition to experimentation, but it includes some development of "hardware" (such as the Speech Communication System Index Meter), and "software" such as the PERTeach course and the Rhyme Test, described earlier.

Progress. A brief description of some of the direct applications work follows:

(1) Two studies of display were implemented when SPO and operational personnel called Decision Sciences Laboratory in as consultants. One was done in connection with SPADATS (Space Detection and Tracking System), and another in connection with System 425L - the North American Air Defense Combat Operations Center. The problem at SPADATS was to decide what kind of map projection, e.g., mercator, gnomonic, should be used to display given kinds of satellite track information (orbit declination, number of orbits and tracks). On the basis of extensive experimentation with observers trained in using the display, DSL was able to make meaningful recommendations.

(2) NORAD called on the laboratory to evaluate a proposed scheme of

colors and finishes to be used in their command and control center. The laboratory was to insure that various established psycho-physical criteria, such as reflection from scope faces and the effect of colors, would be met. Studies directly relevant to these problems had been made earlier, so DSL was able to make immediate recommendations on lighting, colors, finishes, and on the use of an implosion screen for a cathode ray tube display scope designed to increase character legibility and reduce reflection.

(3) The following is a partial list of other contributions which are not described or embodied in the Technical Documentary Reports, but which are nonetheless direct applications to "real world" problems: (1) A study of and specifications for the Strategic Air Command Intelligence Display System. (2) Consultations to Lincoln Laboratory in the design and use of an implicit programming technique for data analysis and manipulation. (3) An evaluation of electroluminescent screens for displaying weather information at different locations around a base. (4) Development of weather forecaster screening techniques. (5) Consultations to the Air Training Command in planning a division to be concerned with designing new instructional systems. (6) A study of personnel hazards, auditory in nature, in communication centers of 482L. (7) A study anticipating display problems for air traffic control after 1970. (8) Participation in the advanced planning for the future Manned Orbital Laboratory.

BIBLIOGRAPHY

(American Institute for Research). SYSTEM 473L, OTC QUERY LANGUAGE, SELF-INSTRUCTIONAL COURSE, August 1964. ESD-TDR-64-443, Project 7682, Task 768204, Contract No. AF19(628)-2935.

Brown, C. R. and Connolly, D. W. (DSL). TED: A TAPE EDITOR, September 1962. ESD-TDR-62-218, ASTIA No. 285472, Project 2806, Task 280604.

Brown, C. R. and Others (DSL). THE CONCEPT OF AN AUTOMATED PSYCHOLOGICAL LABORATORY, July 1962. ESD-TDR-62-191, ASTIA No. 285610, Projects 2806 and 9670, Tasks 280607 and 967001.

Busch, A. C. and Others. THE DATA FLOW ANALYSIS OF A MOBILE ATC AID, August 1962. ESD-TDR-62-190, ASTIA No. 285218, Project 2124 (431L System), Contract No. AF19(628)-244.

Coules, J. and Others (DSL). ON THE SELECTION OF CODE NAMES FOR COMMUNICATIONS SYSTEMS, November 1962. ESD-TDR-62-306, ASTIA No. 292264, Project 2124 (482L/431L System).

Coules, J. and Stuntz, S. E. (DSL). HUMAN ENGINEERING STUDIES OF A MOBILE ATC AND COMMUNICATION SYSTEMS, December 1963. ESD-TDR-63-656, ASTIA No. 429876, Project 482L/431L System.

Edwards, W. (Univ. of Mich.). PROBABILISTIC INFORMATION PROCESSING IN COMMAND AND CONTROL SYSTEMS, March 1963. ESD-TDR-62-345, ASTIA No. 299291, Project 4690, Task 469003, Contract No. AF19(604)-7393.

Fredkin, E. (Information International, Inc.). INVESTIGATION INTO THE SPECIAL PROGRAMMING NEEDS FOR AN AUTOMATED LABORATORY FOR PSYCHOLOGICAL RESEARCH, May 1963. ESD-TDR-63-353, ASTIA No. 427103, Project 7684, Task 768401, Contract No. AF19(628)-1662.

Gildner, G. and Pollock, W. (Bendix Systems Division). STUDY OF COMPUTER MANUAL INPUT DEVICES, September 1963. ESD-TDR-63-545, ASTIA No. 419254, Project 9678, Task 967801, Contract No. AF19(628)-435.

Goodenough, J. (DSL). MODIFICATION OF A PROGRAM SYMBOLIC AT COMPILE TIME. Paper presented at the Digital Equipment Corporation Computer Users Meeting, Livermore, Cal., 14-18 November 1963.

House, A. and Others (Bolt, Beranek & Newman). PSYCHOACOUSTIC SPEECH TESTS: A MODIFIED RHYME TEST, June 1963. ESD-TDR-63-403, ASTIA No. 411983, Project 7684, Task 768403, Contract AF19(628)-382.

Huggins, W. H. (Johns Hopkins Univ.). INVESTIGATION AND EVALUATION OF NEW APPROACHES TO TEACHING SYSTEM THEORY, September 1963. ESD-TDR-63-602, ASTIA No. 420840, Project 7684, Task 768403, Contract No. AF19(628)-263.

Nickerson, R. S. (DSL). THE COMPUTER AS A CONTROL DEVICE FOR PSYCHOLOGICAL EXPERIMENTATION. Paper published in Decuscope, March 1964.

Rath, G. J. and Others (Raytheon Co.). THE DEVELOPMENT OF EXPERIMENTAL PROGRAMS FOR AUTOMATED TRAINING IN DECISION MAKING - HANDBOOK FOR PERTEACH COURSE ADMINISTRATORS, July 1963. ESD-TDR-63-606, ASTIA No. 421776, Project 9677, Task 967701, Contract No. AF19(628) - 365.

Rath, G. J. (Raytheon Co.). BEHAVIORAL PLANNING NETWORKS, August 1963. ESD-TDR-63-607, ASTIA No. 421722, Project 9677, Task 967701, Contract No. AF19(628)-365.

Rubenstein, H. (DSL). HUMANISTIC AND SCIENTIFIC ATTITUDES IN RESEARCH. Paper presented at the Graduate School of Education, Boston Univ. , Boston, Mass. 1963.

Stuntz, S. E. (DSL). SPEECH-INTELLIGIBILITY AND TALKER-RECOGNITION TESTS FOR AIR FORCE VOICE COMMUNICATION SYSTEMS, February 1963. ESD-TDR-63-224, ASTIA No. 402989, Project 7684, Task 768401.

Weiss, E. C. (The Matrix Corp.). A FIELD SURVEY OF A SELF-TUTORING COURSE FOR ON-SITE TRAINING IN SAGE AN/FST-2 TROUBLE-SHOOTING, November 1962. ESD-TDR-62-346, ASTIA No. 296022, Project 416L System, Contract No. AF19(628)-242.

Weiss, M. (Raytheon Co.). PERTEACH VOLS I thru VOL VI, March 1963. ESD-TDR-63-198, ASTIA Nos. 410245, 410273, 411278, 411277, 410244, 409914, Project 9677, Task 967701, Contract No. AS19(628)-365.

FUTURE PROGRAMS

By way of conclusion, a word should be said about the nature of future work as suggested by the research now in progress and by the needs of the Air Force.

Data Presentation and Display

Studies of display characteristics will continue along familiar, but possibly more complex lines. As before, the method of inquiry will center around manipulating display characterists and observing the effect on human information processing behavior. But it is likely that future work will involve more and more complex displays as information systems become even vaster. The corresponding increased complexity of human response will dictate that the study of displays *per se* be extended to include more study of how man interprets and processes data to reach conclusions. The idea that man is a passive receptor of impressions is assumed only in an attempt to isolate as many variables as possible. Actually, data on a display board are only that, until man apprehends them, uses them, makes information out of it. To do so, he must make an active effort to perceive, and that effort is entirely dependent on the motivation, attitudes, feelings, intelligence, biases, and so on, and these are the essence of his humanness. So, the future for data presentation studies will be to examine data less and man more; to understand why, how, and under what conditions he can make meaningful information out of only potentially meaningful facts and figures.

Learning and Problem Solving, Decision Making

In these three very broad and interrelated areas of inquiry about which so little is known, predictions for the future must remain in the most general terms. DSL will continue, as in the past, to define and describe the mechanisms by which men solve problems. Past work, for the most part, has involved only very simple problems in an attempt to control and limit extraneous variables from confounding measurements. As more is learned, though, the complexity of problem structure will be gradually increased. Studies of the kind of decision making peculiar to the stress-filled infor-

mation systems environment will certainly continue to be more and more fruitful as DSL, with the aid of its computer, builds up its facility to simulate rapidly changing conditions, and to isolate and manipulate the many variables present in such an environment. Through experimental work, DSL will continue as it has in the past to investigate and evaluate decision theory as well as to bring to light reliable information on man's data processing capabilities. Promising techniques for designing machines for their human users have already been developed. Decision making studies at DSL will undoubtedly lead to even more promising products than have as yet been developed.

Programmed Teaching and Automated Training

The "training dilemma" arising from the demanding nature of information systems staff jobs is far from being solved. As automation increases, so will the need to train technicians and once trained, to keep them proficient. Although DSL has already contributed significantly to relieving the need, more and better techniques will certainly be demanded of it in the future. More specifically, the long term goals include designating the principles to be incorporated in the design of programmed instruction subsystems, augmenting the technology to be used in developing programmed teaching courses themselves, and making concentrated efforts to develop training courses for decision making and man-computer communication tasks. Perhaps the unknown quantity which looms largest is the Air Force's future implicitly programmed systems. Efforts will be made to explore some of the training problems anticipated for the time when the Air Force begins employing this new programming technique in its information systems.

Communications

The vital contributions to assessing and maintaining voice communication systems will continue. In the near future, the present techniques will be perfected. When standardization and diagnostic evaluation of the talker-listener test is completed, it, the test, will be organized in the form of a preliminary technical manual for field use - probably by the end of FY65. Upon completion of the laboratory tests, the Speech Communication Index

Meter will be tested operationally in working systems in the field. The operational test will probably be completed in FY67.

Communication or information transfer between man and computer in "natural" English is, as was noted, in its infancy, and where to begin the work toward providing such a capability is not the least of the problems. At any rate, DSL has set some modest but well defined and feasible goals for completion in the foreseeable future. The laboratory intends to develop methods and materials for comparing the means of retrieving sentences from computers, and then, in fact, to compare them in terms of the effectiveness of each. The means are two: retrieval by using an associative network, and retrieval by using a fixed index or pre-compiled thesaurus. At the same time, work toward establishing the range of variation for male talkers will continue with an eye to being able, ultimately, to tap computer data files with spoken queries. Experiments to compare three promising techniques for establishing the range are now being conducted, and one technique will be chosen to use in working toward the goal. Studies in these two areas will provide indispensible ground work for programming computers to "understand" man in his own language.

Applications

It is inappropriate to outline any future programs or plans in the applications area. Applications will depend almost entirely on the results of the research outlined previously, and on the needs and requirements of future Air Force information systems. So, as research is completed and Air Force requirements become known, scientists working in the area will attempt judiciously to integrate the two, i.e., the results and the requirements.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Decision Sciences Laboratory, ESD, L.G. Hanscom Field, Bedford, Mass.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A

3. REPORT TITLE

Decision Sciences Laboratory Biennial Progress Report

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

July 1962-June 1964

5. AUTHOR(S) (Last name, first name, initial)

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
Oct 64	42	135

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 7682, 2806, 2808, 4690 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ESD-TDR-64-609 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) None

10. AVAILABILITY/LIMITATION NOTICES

DDC release to OTS Authorized

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This report summarizes the activities of the Decision Sciences Laboratory and describes achievements, progress, results obtained by the laboratory scientists in the past two years.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Human Factors Behavior Learning Perception Memory Decision Making Problem Solving Programmed Teaching Automated Training Man-Machine Interaction Voice Communications Information Retrieval						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
________________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
________________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
________________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional